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ON CLOUD FORMATION.*

PROF. W. VON BEZOLD.

Translated by L. A. BAUER.

MOST commonplace and everyday occurrences shall be the theme of my discourse this evening, — for scarcely a day passes that the skies do not reveal at least one fleecy cloudlet, and how often we find the orb of day hidden from our sight by dense cloud-masses! Nevertheless, the attempt to make the ever-changing forms of this airy structure the subject of careful and scientific scrutiny, was begun very late. I say *nevertheless*, when perhaps it would be better to say *for that very reason*.

Nothing dulls the interest of man so much as the everyday occurrence.

In how large a measure this assertion holds good, the history of meteorology furnishes the most striking example. Although we live in the atmosphere; although our welfare, all our doings and contrivances, above all, the yield of our fields and gardens, — one of the most important sources of national prosperity,— depend upon the weather, nevertheless the study of the great processes unfolding themselves in the atmosphere has but lately been admitted into the circle of the sciences. The beginnings of astronomy reach back to prehistoric times, while meteorology, so often called the sister science of astronomy, since it also

* An address delivered in the "Urania" of Berlin, Nov. 29, 1893, and published in the Urania Journal, "Himmel und Erde," Vol. VI., No. 5. Translated by permission of the author, and by the courtesy of the Director of the Urania, Dr. Meyer, for the AMERICAN METEOROLOGICAL JOURNAL. The four cloud views were made in Berlin expressly for the JOURNAL. With the consent of Prof. von Bezold, Figs. 1, 2, 3 and 9 of the original article are omitted in the present translation; Fig. 4 is replaced by Fig. 1 of the translation, and the original Figs. 5–8 become Figs. 2–5.

directs the eye skyward, can scarcely count a few hundred years. At the very commencement of the Christian Era, a rich store of astronomical data was at hand, but it was not until the middle of the seventeenth century that the first meteorological instruments were invented. Scarcely one hundred and twenty years have passed since weather observations at various stations were systematically begun, collected, and discussed. For this the very fact of the daily occurrence of weather phenomena was not a little to blame. Again and again we have seen that unusual occurrences, such as mighty storms; a great drought, or continuous rains; an especially warm summer, or an exceptionally cold winter, and rare optical phenomena in the heavens, have attracted man's attention and often imparted a new and more or less fruitful impulse to the study of atmospheric processes, while the phenomena which occur the most frequently have been deemed scarcely worthy of observation.

The theory of the rainbow long ago reached a high state of perfection, and comparatively long ago the coronas and halos about the sun and moon, the streamers and the mock suns, as they are observed now and then, could be explained to their minutest detail, while of the simple and yet so beautiful spectacle which unfolds itself in a normal twilight, we did not even possess a complete description based upon actual observation. When the author gave such a description for the first time, thirty years ago, and pointed out how flagrantly all text-books differed from the truth, his paper was entirely ignored.* Just twenty years later, namely, in 1883, when, on account of the Krakatoa eruption, there were over almost the entire earth those remarkable and long-continuing twilights, which many of my hearers doubtless still remember, interest in the matter was thoroughly aroused. Twilight observations were made everywhere, and the old paper was taken down from the shelves, since many observers found that they could not clearly state wherein the unusual twilights differed from the normal ones, as they had never carefully observed the latter.

It would be a simple matter to cite additional cases to the point, but my purpose was only to explain the psychologically

* See Poggendorf Annalen, cxxiii., 1864, pp. 240–276, or Philosophical Magazine, xxx., 1865, pp. 419–424.

strange fact that the study of the phenomenon to be discussed here — cloud formation — was begun so late. As a matter of fact, it was not until the beginning of the present century that a first attempt was made to classify the clouds, at least according to their external appearance, and to find a suitable terminology for them. The honor of having done this belongs to a London merchant, Luke Howard, who, in 1802–3, made the problem the subject of one small treatise and thereby laid the foundation upon which since then every investigation on clouds has been based. Above all he was happy in the introduction of three principal types of clouds, — the sheet or layer cloud, or "stratus"; the mass-cloud, or "cumulus," and feather-cloud, or "cirrus," and in the selection of Latin names, thus making the classification the common property of all nations. Howard's labors, however, did not reach beyond mere description, although he had set for himself a higher goal. The demonstration of the connection between cloud forms and their under-lying causes could not be attempted with success in those days, owing to the slow advance of the science of meteorology.

This question has, in fact, only in very recent times stepped to the foreground of active interest, especially so since it has become possible to call to our aid the use of that powerful instrument of scientific research, photography, with the help of which the ever-changing forms can not only be caught and fixed, but, what is of more importance, their extent, height, and progressive motion can be accurately measured. The problem which here confronts photography is a far more difficult one than might at first be supposed. The chief source of difficulty lies in the fact that the blue of the skies has almost as strong an effect upon the usual photographic plate as white light, so that if the usual photographic methods are used many clouds, in particular the light, feathery ones, do not appear on the plate. Hence there was need of special contrivances, such as the introduction of yellow glasses, the use of specially sensitive plates, etc. It was not until such additional measures were taken that the difficulties of cloud-photography were overcome, and the attempts of certain amateur photographers and meteorologists became successful. Among those whose success deserves special mention may be named Dr. Neuhauss, of Berlin; Profs. Hildebrand-Hildebrandsson, of Upsala, Riggenbach, of Basle,

and Sprung, of Potsdam. We are able to do more with this instrument of research than merely catching the ever-varying cloud forms. We can, namely, combine the camera with an astronomical theodolite, and then, by observing a cloud simultaneously with such instruments mounted at various stations, determine therefrom the height, extent, etc., of the cloud.

Having prefaced with the foregoing, we can now approach the subject-matter more closely. Generally speaking, we may say that clouds or fogs form whenever there is a condensation of the aqueous vapor, which is ever present in the atmosphere in greater or less quantity. The condensed particles may be either liquid or solid, and, according as the case may be, we speak of water clouds or ice clouds. Which kind we have before us may be decided at times from a sufficiently high mountain, or with the aid of a balloon. But even in the more common case when the cloud is inaccessible in this way, we can, in many cases, draw definite conclusions. The means for doing this are furnished us by the beautiful optical phenomena, which we so often see surrounding the sun or moon, and which are known as coronas, or halos, as well as the mock suns, mock moons, streamers, etc. It can be shown that the small rings about the sun and moon which are usually called halos, for short, are caused by the diffraction of light on fine, round fog particles, and hence are the signs of water clouds, while the rings around the sun and moon which surround these bodies at considerable but perfectly definite distances, as well as the mock suns, etc., are due to the refraction and reflection of light on fine ice particles, and hence are the signs of ice clouds. Since these two kinds of clouds generally differ not a little from one another in their external appearance, we can, with a little practice, easily distinguish the particular kind of cloud visible without the mentioned optical phenomena. It is also evident that the ice clouds preferably hover in the higher regions of the atmosphere, since, in general, it is cooler there (in the highest regions always so) than at the earth's surface. But one would go amiss were he to conclude that at temperatures below the freezing point *all* clouds are ice clouds. On the contrary, it occurs quite frequently that clouds possess a temperature far below the freezing point, but still consist of liquid particles. We have the analogous case when we carefully free water of all its air by boiling.

It is then possible to cool the water far below the freezing point without its turning to ice, provided we guard against any shock or disturbance, however slight it be. If, now, we permit a fine ice particle or even a snow-flake to drop into the cold water, a sudden congelation sets in and the temperature immediately rises to the freezing point. This phenomenon of undercooling seems to play an important *rôle*, especially in the formation of thunder-storm clouds.

With regard to the size of these fine ice and fog particles it may be said that it varies considerably. While they are, in general, microscopical bodies, and, as they occur in the coronas and halos, hardly possess a larger diameter than 0.027 mm., they nevertheless become large enough at times to be visible to the naked eye. Indeed, the tiny drops, which in time of a fog descend in the form of a fine spray, are nothing more than unusually large fog particles; and does not the snow cloud consist of those very same snow crystals, whose beautiful and dainty forms have so often delighted the eye?

So much as to the form in which the aqueous vapor is condensed. Let us now turn our attention to an investigation of the conditions under which this condensation takes place. First of all we must call to mind what physics teaches us with respect to the conversion of water into vapor and *vice versa*. It tells us that the quantity of water that can exist as vapor in a definite space, regardless as to whether air is present at the same time or not, varies decidedly with the temperature; thus at 0° Centigrade there can be present in one cubic metre but 4.9 grams of aqueous vapor; at 10° the amount rises to 9.3 grams; and at 20° even to 17.2 grams. If the air contains less aqueous vapor than would be possible at its temperature, and we now introduce water, then as much of the latter will evaporate as will cause that limit to be reached. When this has taken place, we say that the vapor is saturated, or the air mixed with it is saturated, while in the former case we say the air is more or less dry, according to the degree to which the point of saturation is approached. If we now have saturated air of a definite temperature, and cool it, then, since but a smaller amount of aqueous vapor can be present at the lower temperature, a certain amount of water must be precipitated. Suppose, *e. g.*, we have air at 20° saturated, then we have present in a cubic metre 17.2 grams

of vapor. If we now cool the air down to 10° then nearly 8 grams of water must drop out, since at this temperature the air can hold but 9.3 grams in vaporous form. There are, however, certain exceptions to this, of which we shall speak later.

From these facts it will be evident what takes place when moist air is cooled. At first the saturation point is reached and then, with further cooling, condensation sets in. If the cooling has occurred on account of the moist air coming in contact with solid bodies, such as the walls of a vessel, then the walls will be covered with water or snow during the act of condensation. If, on the contrary, the cooling has taken place throughout the entire mass of air, the condensation appears as fog. But the process of fog formation is not so simple a one as has been portrayed, and as was formerly thought sufficient, for really fog is formed only when the cooled air contains, besides the aqueous vapor, finely divided solid particles, such as smoke or dust. Had we air which had been carefully freed of all such impurities, then no fog would result, even after the saturation point had been passed. Indeed, a larger amount of vapor remains present than could possibly be contained in the same space at the same temperature by the simple process of evaporation — the air is "supersaturated." This phenomenon is similar to that which occurs when water is cooled below its freezing point.

Not long ago it was shown that the presence of such solid nuclei is absolutely essential for the formation of fogs or of clouds. It is this matter which is of the highest importance for the discussion of the subject in hand. In this manner, we can, for example, explain the strong inclination for fog forming over large cities, especially over those with highly developed industries. We can now appreciate the truth of the well-nigh proverbial phrase, "London fog and London smoke," and can perceive its inner significance. How close the relation is can best be seen from the fact that, according to Prof. Auwers, the number of days per year on which the sun can be seen at noon at the Greenwich Observatory, London, has decreased since the middle of the last century up to the eighth decade of the present century from 160 to 115 — 45 whole days less! To obtain an idea as to the extent to which such solid particles are present in apparently pure air, we may state that the Englishman, Aitken, to whom we are most especially indebted for these investigations,

found on the Rigi, Switzerland, on a bright day, 700 such solid, tiny bodies in every cubic foot of this far-famed, pure Alpine air. In a cloud covering one of the peaks he was able to reveal 4,200; but in the air near the ceiling of a room in which four gas-jets had been burning two hours he found not less than sixteen millions of smoke and dust particles in every cubic metre.

According to these explanations the problem of cloud formation now hinges chiefly upon the investigation of the conditions under which cooling in the atmosphere takes place. This can, in general, occur in three different ways: 1, by imparting heat to the cold earth or ocean surface; 2, by the mixing of two unequally warm, saturated, or nearly saturated, air masses; 3, by the expansion of air in consequence of change of pressure without the simultaneous supply of a sufficient quantity of heat.

Of these three different ways, the last is the most productive and, therefore, to it falls the lion's share in the formation of clouds and rain. It is a simple matter to obtain a clear picture of the working of these processes with the aid of a few experiments. Fill a beaker about one third with water, and heat the latter in a sand bath up to about 50° or 60° C., taking care to cover the top of the beaker with a glass plate. The space over the water will completely fill itself with vapor which, however, is invisible since the sides of the beaker have been heated at the same time, thus preventing condensation in the form of fog or water. Should a slight condensation have occurred, however, it can readily be dissipated by shaking the beaker. Now let us remove the glass cover and insert in the vapor-filled space a smaller beaker containing some pieces of ice. The sides of the second beaker will at once be covered with moisture. Furthermore, by the mixing of the cooled air gliding down the cold beaker with the warm vapors, a dense fog will be formed, which sinks down upon the surface of the warm water. This experiment illustrates the first two processes.

The third, fog formation by adiabatic expansion, can be made clear by the experiment of Prof. Kiessling, of Hamburg. Take a large glass balloon containing a little water and closed at the neck by a cork, through which passes a glass tube provided with a stop-cock. Let us first rarefy the air enclosed in the balloon by suction with the mouth at the end of the glass tube, and then close the stop-cock. If we now open the stop-

cock, air will rush into the balloon, and at the same time carry with it a little smoke from a fire-sponge held in front of the tube. Or, what is preferable, take, instead of a sponge, a common match (not a safety match) and let a trace of the vapor of the burning sulphur pass into the balloon. Then force additional air into the vessel with the mouth, and again close the stop-cock. We have now inside the balloon moist compressed air. If we now let this air rush out rapidly, by suddenly opening the stop-cock, expansion of the air follows, in consequence of which cooling sets in and the balloon fills itself with fog. Had we, however, previously freed the air of all dust by shaking it with water, no fog would have appeared. It was for this reason that we found it necessary to introduce a little sulphur vapor.

We are now ready to investigate how these different ways of cooling are turned into account by nature, and how they influence the shape and form of fog and cloud. We will begin with the first process — cooling by contact with a colder body. This we meet with when the ground or the water surface has cooled itself by radiation, *i. e.*, during the morning, evening, and night-hours — in winter, also at day — when the absence of clouds and the calm air are favorable to the process of radiation. Here the surface of the earth first covers itself with fog, the so-called ground-fog, which when it has once been formed continues to grow in height from the ground upwards so long as the conditions are favorable, for the radiation, when the fog has begun, takes place always from the topmost layer and hence a continual building up of fog must result. Should the ground now warm itself by insolation during the day, however slight the effect of the fog-penetrating rays of the sun may be, the lowest layers will dissolve and we have high fog developed. In other cases the dissipation of the fog begins at the top and proceeds downwards, the lowest layers remaining the longest. With regard to the thickness of these fogs, we may state that at times it may become quite considerable, as much as 1000 metres or more, while in such cases as ground-fog we must reckon by centimetres. The form of the fogs described here is usually a simple one, viz., horizontal layers, which break up into trains only when a wind blows over them, or when they are in the last stage of dissolution. When, however, air of a different temperature glides over the upper surface of the fog, then a most remarkable

occurrence sets in of which, in connection with others, I shall speak later on. In such cases the fog surface is cut up into regular billows and thus presents a similar appearance to the storm-tossed sea. As to how far the cooling by radiation in higher regions also is to be taken into account, and as to how far this factor furthers the development of already existing clouds, remain open questions for the present.

Far more manifold than the forms just spoken of are those which arise from the second process, that of mixture. Since the mixing can take place layer-wise, as *e. g.* in the superposition of unequally warm and hence of unequally heavy strata, or can proceed in curls and whirls, as occurs in the agitation of a liquid by stirring, just so must the clouds formed by this second method consist either of horizontal strata, like the ground fog, or they must show curly, variously-shaped configurations. In this process of mixing we have to deal with a state of things peculiar to itself. For, firstly, the quantities of water which are condensed in this way, even if both mixing masses are saturated, and their temperatures are different, are never very considerable. This process can, in consequence, never be the cause of heavy cloud formations, and still less the source of copious precipitation. Secondly, condensation can accompany the mixing of two imperfectly saturated masses of air only so long as the mixing proportion remains within certain limits. Let us suppose *e. g.* that we mix air of 0° C. temperature and saturated 95 per cent with air saturated also to 95 per cent, but having a temperature of 10°, then will water be produced so long as the relation in which the cooler air was mixed with the warmer is not smaller than 23:77 and not larger than 61:39. When, therefore, a mass of air of definite temperature penetrates into another of a different temperature, it will often occur that with the ever-varying mixing proportion only light, ephemeral clouds will result which, as the process continues, at once dissolve again. In this way arise those light, ragged cloud shreds which are very frequently seen when the air moves quite vigorously; they are in a constant state of very rapid change. At the edge of mighty cumulus clouds, whose origin we shall discuss presently, we can also notice similar appearances that are due to mixture.

We may observe most instructive examples of this kind of cloud formation now and then in mountainous regions. Such a

case was observed by me several years ago and described in *Himmel und Erde*, Vol. 2, p. 15. This I shall briefly describe again here. Of the mountains which border on the north the Pflersch Valley (Tyrol), running from west to east, and lying in the Brenner Pass which connects Southern Germany with Italy, the pyramid of the so-called Pflersch Tribulaun occupies the most prominent position (in the background of Fig. 1). East of the Tribulaun (in the foreground of the figure) the mountain chain has a cut in the form of a yoke, which permits passage

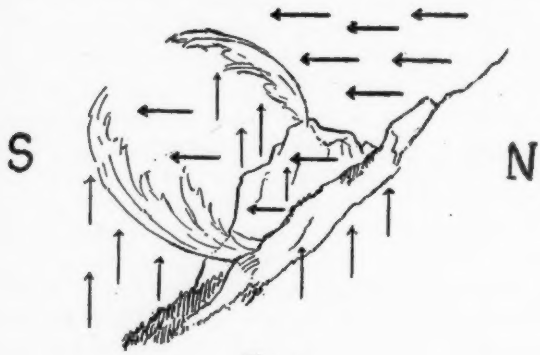

Fig. 1.

from the Oberberg Valley on the north to the Pflersch Valley on the south. On bright days the sun's rays strike the southern slope of the chain from morning till night, so that, if the motion of the air is not violent, a vigorous, warm, ascending current, indicated by the light arrows, is developed. If, now, the general circulation of the air is such that air is driven southwards, then this air coming from the north (shown by the heavy arrows) passes through the above mentioned mountain yoke, and strikes the warm ascending current on the other side, and is, in consequence, bent upwards by the latter. When, then, the humidity conditions are favorable, a cloud due to mixing air-currents must result, which turns its *convex* side towards the Pflersch Valley, (see banner in foreground). The Tribulaun, however, which towers to a greater height, conducts the ascending currents into the upper currents prevailing on the northern side. In consequence, the ascending current is deflected southwards, so that the cloud banner now formed turns its *concave* side towards

the valley, *i. e.*, exactly the reverse of the first-named banner. (See background of figure.)

The clouds which arise in this way, as is clearly evident, are of a very ephemeral nature ; they are thin, delicate veils which, only under exceptionally favorable circumstances, are as far developed as has been described and figured here. Far more permanent are those clouds which are caused by the mixing at the boundary of two superimposed air *strata*, and which themselves wear the impress of the horizontal layer in the most perfect degree, and have, therefore, well earned the name of layer or sheet-cloud, Latin *stratus*. They appear frequently as a homogeneous sheet covering the entire sky, making it extremely difficult to judge of their thickness, except, perchance, they be penetrated by balloonists. More frequently they are accompanied by other phenomena, the explanation of which was given several years ago by Prof. von Helmholtz on purely theoretical grounds, and which open up to us some of the most interesting vistas. Helmholtz, namely, proved that when a layer of air glides over another one of different density, *i. e.*, of different temperature, waves must arise just as when the wind blows over a corn field or over a water surface ; only these waves are of totally different dimensions from those of the water or those of the corn field ; the distance between two consecutive wave combs, or, as the physicist expresses it, the wave-lengths, is, as Helmholtz has shown theoretically and as experience has verified relatively, vastly greater. While the wave-length of the usual water waves can be counted by metres or by many metres, as is the case with ocean waves which may, in exceptional cases, reach a length of 100–200 m., the atmospheric waves are to be reckoned by hundreds of metres ; oftenest, indeed, by several kilometres. These waves become visible as soon as the mixing *strata* possess sufficient moisture. At those places which correspond to the wave summits, masses of the one stratum are forced into the other ; in consequence of this, a succession of rolling clouds is thrown up in the form of parallel rows. Helmholtz has very aptly termed them billow clouds. Figs. 2 and 3 of the cloud plate, which are reproduced from the photographs of Dr. Neuhauss, show such billow clouds.

If, at any point of the separating layer, a similar wave system is excited by a wind coming from a different direction, then

cloud rows which are already formed will be cut up by this second system so that the whole stratum falls into rhombic-like figures, and thus arise the so-called sheep or lamb clouds. This name is, however, only given when the clouds are suspended at such a height that many of then are seen at once, so that, as a whole, they present the appearance of a flock. In truth, we encounter these billow waves in the most different altitudes, though, in general, they belong rather to the middle and higher atmospheric regions than to the lower. As a matter of fact not only has the upper surface of the fog ocean covering the earth been seen from the top of high mountains and from balloons arranged in such parallel trains, but Lieutenant Gross * and Dr. Berson * on a balloon trip made Nov. 10, 1893, observed that a fog reaching scarcely more than one hundred metres above the earth's surface had its upper surface cut up into many hundred rows, which sought to run in parallel to the edges of large woody areas that remained fogless, just as the comb of the breaker adapts its form to the trend of the shore line. But Dr. Jesse, of Steglitz, near Berlin, whom we must thank for those beautiful investigations of the luminous night clouds, has even succeeded in showing photographically this same form ranging in parallel rows in the case of those delicate cloud creations which hover at altitudes where the pressure of the air is less than one ten-thousandth of that at the earth's surface, and the air consequently thinner than in the so-called vacuum of our test air pumps. Unfortunately, the name of "billow clouds" has not yet been generally accepted by meteorologists, so that in the classification of the clouds that fall under this class stress is laid upon other characteristics, viz.: —

If the rhombic-like division is present, or, as popularly expressed, if they are lamb clouds, then they are termed, as long as they still possess considerable mass, *alto-cumuli*, which are high floating mass or cumulus clouds, *i. e.*, belong to middle atmospheric regions, or to heights of 3000–5000 meters. In this case they will consist mostly of water particles or of snow crystals.

If, however, they are exceedingly delicate, as is the case with

* The gentlemen who have carried out most of the successful balloon trips made under the auspices of the Berlin Meteorological Institute with means furnished by the Emperor. — L. A. B.

Fig. 2.

Fig. 3.

CLOUD VIEWS.

From Photographs by Dr. Neuhauss and Prof. Riggenbach.

Fig. 4.

Fig. 5.

CLOUD VIEWS.

From Photographs by Dr. Neuhauss and Prof. Riggenbach.

those clouds constructed of fine ice particles suspended in the highest atmospheric regions, then we call them *cirro-cumuli* or feathery cumulus clouds. We see, then, that in both cases the fact is considered whether the individual clouds, of which the whole stratum is composed, form rounded masses, reminding one of the cumulus cloud, which we shall consider later. Formerly, also, we spoke of roll cumulus when there was no cross-furrowing, and when we were dealing with lower clouds. Or, of polar bands, when emphasis was to be laid upon that particular parallel arrangement in which the various rows would all seem to converge to one point, the pole, owing to the effect of perspective. At present also these formations are frequently termed alto-cumuli or cirro-cumuli in cases where they occur very high up and the rows appear narrow and very long, or briefly, also, cirrus or feather clouds. If, on the contrary, we go back to the law of formation and do not consider the single parts of which the stratum is made up, then the chief stress must be laid upon the stretching out in a horizontal sense and these clouds be distinguished as "single-furrowed" or "double-furrowed" layer clouds. We can therefore still speak of cumulo-stratus, alto-stratus, or cirro-stratus, according to whether they are at moderate, intermediate, or extreme heights. How important the introduction of a terminology based upon the inner character of this very kind of cloud is for the proper understanding of atmospheric processes may best be shown by our later discussions. But first we must give the proof that we actually are dealing here with billow clouds. Aside from the mathematical difficulties mentioned, the matter may, perhaps, be made clear by the following remarks:—

First, these regularly arranged rows have the peculiarity that for a considerable stretch over the sky they arise almost simultaneously, as though by one blow. By this it may occur that a large part of the previously clear sky may suddenly cover itself with clouds, or that a cloud sheet already at hand is all at once cut up into furrows, while the clouds proper slowly travel onward. This sudden origin of parallel trains of clouds finds a perfect analogy in the case when a wind suddenly strikes and glides over a water-surface, rippling it into many hundred wavelets. Balloonists have, moreover, shown that such comparatively thin cloud sheets really form the boundary between two strata

of different temperatures, and that the furrows occur when the layer is at the same time the separating surface between two currents possessing different velocities; and in this way the assumption made by Helmholtz in his mathematical proof is found to be correct.

Viewing the billow-cloud formation from this standpoint, we see that in these regions we have a dividing layer that fulfils the above requirements, and the frequency of the occurrence shows us that the flowing of different air currents over each other is one of nature's commonest events. The careful observation of these "billows," therefore, furnishes us with a most powerful auxiliary to the study of atmospheric motions.

Thus far we have spoken of but relatively light formations which, though they may obscure the sun more or less, never can be the source of bountiful precipitations, nor even of precipitation worth mentioning.

The shiny white mass or cumulus clouds, which on warm summer days pile themselves up like mighty cliffs, or the threatening black thunder-cloud that towers up even more majestically, only to deluge hill and dale with refreshing rain or cover them with destructive hail, have not received any attention. These clouds, of which Fig. 4, reproduced from Prof. Riggenbach's photograph is a sample, arise under totally different conditions from those hitherto investigated. To make this clear we can content ourselves with a mere superficial inspection and can omit a rigorous mathematical investigation. Cooling by contact with colder bodies or by direct radiation within the atmosphere can at once be shut out from the category of formative causes, since these clouds occur most frequently on the hottest days and at the hottest season. No more can the second way of cooling — that of mixture — be the operative cause, since it cannot be effected throughout large masses, but must confine its action to the surface, so that if cumulus clouds were formed in this way, they would have to be hollow. These clouds owe their existence rather to the third method, namely, the cooling of ascending currents. The higher we ascend in the atmosphere the less the pressure becomes. Hence air that comes from below must continually be expanding itself, since volume varies inversely as pressure. This expansion is very considerable. By rising to the elevation of 3,250 metres, *i. e.*, somewhat

higher than the Hoher Sonnblick, until recently the highest meteorological station in the Alps, the air increases its volume by one half of its original volume, and at a height of 5,600 metres the original volume is doubled. We have, therefore, the very same conditions as in the case of the Kiessling experiment which we carried out. Clouds must hence form and be accompanied by a generous production of water. We are forced to conclude, then, as figures have shown, that this last method is the cause of the most copious precipitation.

That the summer cumulus cloud is to be referred to the ascending currents which are kept up by the heat of the day was known long ago. The full significance, however, of this process, which gives us now the key to the whole theory of precipitation formation, was first appreciated when the study of those remarkable occurrences, which are peculiar to high mountainous regions and which are known in the Alps as the warm wind or foehn, was taken up. I have already described in another place ("Himmel und Erde," Vol. II., page 9) such a foehn phenomenon, but will briefly mention the salient points again. You are probably familiar with the fact that now and then, in the northern Alpine valleys, a storm rushes down from the summit of the Alps that is noted for its heat and its extraordinary dryness. On account of these two properties it was formerly thought that the origin of the foehn was to be attributed to the Sahara. But when sufficient meteorological records were at hand, we learned, about thirty years ago, that the coming of the foehn in the Northern Alps was always accompanied by abundant precipitations on the southern slope, and that the wind which arrives warm and dry below assumes these properties first in the act of descending, and was still cold and moist on the summit. It was found that every time the foehn blew, the general air pressure distribution over Europe was such a one that great quantities of air would be drawn or pressed over the Alps from the south side. When this was recognized it was soon observed that this phenomenon was not a local one, but set in wherever the air had to climb over lofty mountain chains.

The explanation of the foehn now lies at hand. As soon as the air on one side of the mountain ascends it expands and, in correspondence thereto, cools itself just as the compressed air in

our glass balloon, with which we experimented, expanded and cooled when we opened the stop-cock. A point will soon be reached where, at a given altitude, the vapor will be saturated; crossing this point, the expansion and cooling still continuing, condensation of vapor must set in and hence clouds will form and water be precipitated in the form of rain or snow. When the summit has been scaled, the air, though saturated, nevertheless contains less water than it did before it began to climb. As soon, however, as it begins to descend on the other side, with increase of air pressure it will suffer a compression and in consequence be warmed. It must, therefore, at once become relatively dry, and when reaching an altitude where it has the temperature it possessed before the ascent, is much drier than it was originally, since in the meantime water vapor has been lost. Now, as for various reasons (for which I must refer you to the paper above cited), the original temperature is reached before the air has come down to the starting level, and since in further descending the warming continues, the air must arrive at the base warmer than it was at the corresponding altitude on the other side. Moreover, since at this higher temperature it does not even possess the original quota of water, it must be likewise extraordinarily dry.

This process is accompanied by cloud-making peculiar to it. At the summit of the mountain, where the air current arrives at its turning point and the ascent changes into a descent, cloud masses heap themselves up into a mighty wall which, though the individual parts may have motions of their own, yet as a whole does not appear to move from the spot, and which in consequence has been given the name of foehn-wall. This is a very interesting example of a series of cases where a cloud apparently stands still but, nevertheless, is shaken through and through by a powerful storm, — a sober warning not to deduce the motion of the air directly from cloud motions. It frequently happens that a cloud is at the same time engaged in the act of formation and of dissipation, so that the composing particles are swept away with great velocity only to have their places supplied by new ones. Similar conditions to those here described are encountered in every case of an ascending current, regardless of whether the current is produced by local heating, as in the case of the summer cumulus cloud, or whether it be

because we are in a region of barometric depression towards which from all sides air rushes in below, only, of course, to flow out again at the top, and thus bring into play an ascending current. In both cases clouds result which show moderately heaped-up shapes, since here the condensation takes place throughout the entire mass, and because the ascending current forces itself into the superincumbent cloud masses, whereby round, blunt demarcations must arise.

The summer cumulus cloud has a level base corresponding to the height at which the dew point is reached by the ascending current; the large rain cloud, on the contrary, which is really nothing more than a cumulus cloud, whose upper surface, however, is hidden from us, shows at the bottom usually an irregular fringed configuration, a peculiarity that, to be sure, appears distinctly only in mountainous regions where the demarcation can stand out boldly from the background. This is one of the results of the process of mixing which in this case, in connection with the chief cause of cloud making, plays a definite *rôle*, though it be but a secondary one. These fringes appear when the motion of the air is quite lively, and from their forms we may gather that the ascending current proceeded in inclined directions, whereby condensation at the various points began at different heights, according to the degree to which the ascending currents could saturate themselves at the earth's surface. The cumulus clouds show, occasionally, an enormous development in thickness. Indeed, even the ordinary rain cloud whose bottom surface may not be more than a few hundred metres above the earth or above the valley bottoms, and may not infrequently even hang lower, may nevertheless often tower beyond the highest Alpine peak. Yet greater thicknesses at times are assumed by the thunder-clouds. For example, Prof. Riggenbach observed at one time from the Saentis (Switzerland) a mighty thunder-cloud hovering over the Algaen Alps (southwestern part of Bavaria), whose base from actual observations was 2,800 metres above sea-level, while the highest cloud peaks loomed up to 13,000 metres above sea-level or to more than double the height of Mont Blanc (4,810 metres). It is probable, also, that in the making of thunderstorm clouds other peculiar conditions enter into play that impart an additional strength to the ascending current, so as to make it possible that the water

particles reach such unusually great altitudes. Such clouds, in fact, often contain undercooled water. If, while in this state, a slight disturbance is experienced as, *e. g.*, by the mere dropping of a snow crystal from a greater height, the unstable equilibrium is at once broken, congelation sets in, the temperature rises, and thus suddenly a new upward impulse is given. Such an undercooled cloud carries, then, in a certain sense, a spring of energy with it, and perhaps we may seek herein the cause of those powerful transformations of shape which the thunderstorm cloud undergoes. This may be the cause of the sudden puffing up and the shooting forward of new cumulus peaks which often in but a few minutes heap themselves to great heights. Should there be present in addition supersaturated air, which, by the way, has not yet been proven but is quite probable from various reasons, then must all these processes receive still further co-operation, and perhaps here may lie the secret of the so-called cloud bursts.

In the foregoing, it has been shown how the majority of the more frequently occurring cloud-forms can easily be explained from the manner of their making, and how we are able to judge their origin from the form. That, by the combination of the enumerated causes, intermediate stages may result is plain, and perhaps it may not be all too difficult to refer these intermediate forms also to the processes and principles here developed. One single form remains which belongs to the very highest regions of the atmosphere, — the so-called wind trees, and usually designated as feather clouds, cirrus or cirro-stratus. Of this form I cannot, at present, give you a satisfactory explanation, at least not in all cases. But this is certain, that those delicate creations consist of ice-particles and occasionally also they may be relegated to the billow-cloud kind. To explain, however, the many varying forms in detail does not yet seem possible. A reproduction of such a cloud form is given in Fig. 5, after Dr. Neuhauss. This is a problem reserved for the future. Its solution seems all the more worthy of attention since it is these very clouds that bring to us the message of atmospheric processes unfolding themselves in the remotest atmospheric depths, and which may with right be regarded as the forerunners of coming weather changes. For it happens, not infrequently, that a barometric depression hovering over the Irish Sea drives such

cirrus clouds beyond the Alps, while in the lower atmospheric regions the circle of action must be a more limited one. But, disregarding this gap, and in spite of the fact mentioned of the everyday occurrence of the phenomena spoken of here to-night, I hope that my remarks may incite some one to observe these very phenomena with different eye hereafter. As soon as he has once begun to observe them more attentively, and can read the history of their formation from the form and constant changes of the cloud, then will these commonplace occurrences, aside from their æsthetic effect, win for him a more characteristic, deeper, penetrating charm, and he will feel re-echoing in him those wonderful words which Goethe puts in the mouth of the Spirit: —

"In the tides of Life, in Action's storm,
A fluctuant wave,
A shuttle free
Birth and the Grave
An eternal sea,
A weaving, flowing
Life, all-glowing,
Thus at Time's humming loom 't is my hand prepares
The garment of Life which the Deity wears!"

SUMMER HOT WINDS ON THE GREAT PLAINS.*

I. M. CLINE, M. D.

[In this JOURNAL, Vol. IX., 1892–93, pp. 437–443, Dr. I. M. Cline, Local Forecast Official at Galveston, Texas, gave an account of "Hot Winds in Texas, May 29 and 30, 1892." Previous study of these hot winds had been made by Mr. Geo. E. Curtis, who published a paper entitled "The Hot Winds of the Plains," in the Seventh Biennial Report of the Kansas State Board of Agriculture, Topeka, 1891, part II., pp. 162–183. Dr. Cline has recently made a more extended investigation of these winds, and his second report in this connection has appeared in the Bulletin of the Philosophical Society of Washington, under the title, "Summer Hot Winds on the Great Plains." This most recent publication contains an account of the hot winds observed from 1874 to 1892, and of the general meteorological conditions prevailing at the time of their occurrence, together with a description of the general characteristics of the summer hot winds of the Great Plains, and conclusions as to their causes. The following pages are reprinted from Dr. Cline's latest paper, and present his conclusions on the subject. — *Ed.*]

ONE of the most striking features of these winds is that while the atmosphere is heated generally and shows an excess of temperature over the territory affected, abnormally heated narrow currents are often observed between which the

* Reprinted from the *Bulletin of the Philosophical Society of Washington, Vol.* XII., 1894. *pp.* 335–348.

air is much cooler. These currents are of very short duration, but often occur in rapid succession at neighboring places. These hot currents occur in groups, covering, as a rule, a territory of a few hundred acres. The currents are separated from each other by only short distances, ranging from a few yards up to a few hundred yards. Sometimes groups of hot winds separated by only a few miles cover several counties, and again several miles intervene between such groups. In this manner an occurrence of these winds sometimes covers the whole or part of a State or two or three States.

The tremor of heat, similar to that seen rising from a hot furnace, is sometimes distinctly visible in these currents. Observers who do not note the distinct currents, as well as those who record this feature, refer to these winds, as a rule, as "hot winds," and not a hot wind. We have no definite record of the temperature of the "hot winds"* themselves, but the thermometers in the affected district range generally, during the prevalence of these winds, from 100° to 110° in the shade, and at times even higher. During hot winds in Texas, July 18, 1886, the thermometer at Abilene registered 109.8° in a standard roof shelter of the Signal Service. The temperature in the sun was taken by myself and others, and 140° was recorded at a short distance from the office instruments, with wind blowing from seven to fourteen miles per hour from the south, except at 1.21 P. M. (local time) when it was southwest. During hot winds in Texas, May 29, 1892, a rise in temperature of seven degrees was noted between 5.01 P. M. and 5.11 P. M. (local time), an hour of the day when the temperature should have been falling. The local and special hot winds (hot currents), as noted in connection with a general hot wind, is a characteristic which I do not find to have been noted in connection with the warm winds of other regions in this country or elsewhere, notably the foehn, the chinook, the simoom, etc., and this feature of the hot winds in summer over the eastern slope of the Rocky Mountains had been overlooked in previous discussions.

The hot winds are likely to occur between May 15 and September 15, but are most frequent during July and August,

* The term "hot winds" in this memoir will refer to the intensely heated currents, while the term "general hot winds" will refer to the movement of the generally heated atmosphere prevailing with such hot current.

and the thirty-five periods of which we have records are distributed as follows: May 1, June 4, July 16, August 13, and September 1. The length of time during which a period of these winds is likely to prevail varies from a few hours to three days. Sometimes, but rarely, two or three of these periods of hot winds follow each other in rapid succession. Some observers have only noted these winds during the day; others have noted them continuously for twenty-four hours, and even longer, while others have observed or rather experienced them only at night, and they have often been noted as continuing into the night. During the hot winds in Texas, July 18, 1886, the temperature at 9.21 P. M. (local time) stood at 96°, with wind eight miles per hour, from the south.

The hot winds are always referred to as extremely dry. Although very few hygrometric observations have been made in connection with them, yet those on record confirm the general statement regarding this condition. Prof. F. H. Snow, of the University of Kansas, recorded a relative humidity of 7 per cent at Lawrence, Kansas, and the observer of the Signal Service at Leavenworth, Kansas, recorded at 5.48 A. M. (local time) 90; 9.48 A. M., 52; 1.48 P. M., 17; 5.48 P. M., 17, and 9.48 P. M., 22 per cent, September 12, 1882. On September 13, 1882, the observer at Leavenworth recorded the relative humidity at 5.48 A. M. (local time), 45; 9.48 A. M., 41; 1.48 P. M., 20; 5.48 P. M., 14, and 9.48 P. M., 20 per cent. On the 14th, 5.48 A. M., 50; 9.48 A. M., 25; 1.48 P. M., 13; 5.48 P. M., 18, and 9.48 P. M. 44 per cent. On the 15th, 5.48 A. M., 63; 9.48 A. M., 46; 1.48 P. M., 29; 5.48 P. M., 28, and 9.48 P. M., 51 per cent; after which there was as decided an increase in moisture as there was a decrease after the 11th and the morning of the 12th. The observer of the Signal Service at Dodge City recorded the relative humidity on September 11, 5.27 A. M. (local time), 48; 1.27 P. M., 14; 9.27 P. M., 24 per cent, which is about one half the per cent recorded on the preceding date. On the 12th 5.27 A. M., 32; 1.27 P. M., 12; 9.27 P. M., 47 per cent. On the 13th, 5.27 A. M., 48; 1.27 P. M. 15, and 9.27 P. M. 48 per cent. On the 14th, 5.27 A. M., 37; 1.27 P. M., 11, and 9.27 P. M. 66 per cent. The last observation of the day shows a sudden and decided increase in moisture, which continued and was as marked as the decrease from the 10th to the 11th. During hot winds

in Texas, July 18, 1886, the relative humidity recorded at the regular observations at different times during the day was as follows: 5.21 A. M. (local time), 39; 9.21 A. M., 20; 1.21 P. M., 16; 5.21 P. M., 16, and 9.21 P. M. 18 per cent, at Abilene, Texas. The above records of the moisture in the generally heated atmosphere were made without reference to the occurrence of the special hot winds; hence the per cent of moisture within these must approximate closely to zero.

The records of stations near localities from which hot winds have been reported have been examined for several periods of such winds and the conditions are found in all cases examined to be similar to those noted in connection with the above stations.

The direction from which the hot winds blow is the same as that of the atmosphere near the earth's surface prevailing over the section in which they occur at the time of their occurrence, and is generally southwest or south, sometimes southeast, and frequently from a northerly direction in some sections — particularly the extreme western portion of Texas, as the conditions under which hot winds occur in that section give northerly surface winds. The velocity of the hot winds varies considerably in different periods. It is sometimes noted as a light breeze and from that to a gale. It is not the same in all sections on the same date; while it is blowing a gale at one place it is noted as a light breeze at another place less than one hundred miles distant.

The region of the atmosphere in which the hot winds occur has a well marked progressive movement from west to east; at least, this is found to be the case whenever the data have sufficed to afford an opportunity to look for this feature. The dryness attending the hot winds in Kansas, September 11 to 14, 1892, appeared one day earlier at Dodge City than at Leavenworth, and ceased one day earlier at the former place than at the latter. The eastward progression is also clearly shown by the reports of hot winds in Texas, May 29, 1892, where they can be distinctly traced from the western portion of the State, where they appeared about noon, to the eastern portion, where they were not noted until as late as 10 P. M.

A striking characteristic of the hot winds is their effect on vegetation. While they are always noted as causing vegetation

to wilt and droop, the more intensely hot winds burn tender vegetation to a crisp in a few minutes, without relation to the amount of moisture present in the soil or general atmosphere. Some of the most destructive of these winds have been known to occur when both the soil and atmosphere were saturated with moisture. The tops of corn and other hardier vegetation are burned, while near the earth they are not damaged. The leaves of trees dry to a crisp in some instances so that they crumble at the touch of the hand, and apples bake on the trees. Corn when in silk, and wheat when in dough, suffer more severely than at any other stage of their growth. Wheat in this stage when affected suffers severely. The heat and rapid evaporation completely dry up the germ wherever the hot winds strike. Fortunately, severe damage from hot winds is not general over an affected district, but covers only small parts of the different farms. Sometimes entire counties remain uninjured. Under the influence of these winds the skin becomes dry and parched and perspiration becomes entirely insensible. The more intensely heated currents are said to be almost insufferable. When a period of hot winds continues for two or three days, and the general atmosphere becomes very hot and dry, vegetation suffers generally, but as a rule it recovers, except in those streaks visited by the intensely heated currents, although the yield is reduced somewhat and is reduced materially if two or three of these periods follow each other in rapid succession, as has sometimes been the case.

Prof. J. T. Lovewell,* speaking of the damage to crops in 1887–88, says: "During both these years we heard many complaints of blighted crops, but the cause was not wholly a dearth of rain. When the hot period of July came during the last season (1888) it was accompanied by a high, scorching, southwest wind which prevailed for several days, sweeping from the southwest corner up through the middle of the State, and cutting short the corn crop through the breadth of several counties. These hot winds contribute more to the failure of crops in our State than does the lack of moisture in the soil."

In studying the distribution of pressure in connection with

* In Sixth biennial report of the Kansas State Board of Agriculture. 8°. Topeka, 1889, part 2, p. 214.

hot winds it is found that they occur mostly with low pressure areas which have moved slowly from the north of Montana southeasterly along the eastern slope for three or four days before they take up a decided movement eastward. They sometimes accompany a low pressure area which develops over some part of the eastern slope and remains nearly stationary, or moves slowly north or south along the eastern slope for a few days before moving off, and occasionally they accompany low pressure areas which have moved slowly across the divide from the Pacific coast and then move slowly north or south along the slope before moving off eastward. Of the thirty-five periods of hot winds, twenty-eight occurred with low pressure areas which have moved southward from northwestern Montana. One accompanied a low pressure area which moved from the Pacific coast across the divide to the central slope, and the remaining six developed over some part of the eastern slope. The low pressure area accompanying twenty-six of these periods was of an elongated or elliptical form and extended south from Northwest Territory, generally to the thirty-fifth parallel of latitude, and in some instances to western Texas. These may be described as V-shaped. In nine of these, there were secondary depressions in the vicinity of the hot winds. In the other nine periods of hot winds (not included in the above), there was a general low pressure area along the eastern slope, and this sometimes extended eastward to the lakes and central valleys. In four of these there was a general, well defined, cyclonic movement, while in the other five there was a well defined secondary low pressure, in the locality in which the hot winds occurred. During the development and progress of all these low pressure areas, the barometer was generally about thirty inches or above along the western coast of the United States between the thirty-fifth and forty-eighth parallels of latitude. The eastward movement of the atmosphere from the Pacific slope across the divide toward the low pressure area was generally well defined, and cloudiness, with more or less rain, prevailed from the Pacific coast to the summit of the Rocky Mountain divide. The hot winds are generally found near the innermost or the second isobar of the low-pressure area which they accompany, and their direction, like that of the surface winds, conforms to the trend of the isobars.

The existence of a particular class of winds in summer over the eastern slope of the Rocky Mountains or any part of it has been denied by some who have studied the subject and who claim that the term "hot winds," as used by the inhabitants of that section, applies to winds which occur under the same conditions and are of the same generic character as the warm wave or heated term of the eastern States, and that their dryness and heat are caused by drought and *insolation* * at the earth's surface. This view is strongly supported by Mr. Curtis in his paper on hot winds, already cited. On the other hand, in studying the detailed reports of these hot winds we find many features for which drought and insolation will not account, and it appears evident that we have here a well defined and peculiar class of winds similar to the chinook † and foehn, ‡ but differing in some respects from any winds previously noted. Conditions which will theoretically account for one case of these winds must be present in other cases where such winds are well defined. The theory that these winds are the result of drought and insolation will not account for certain intense periods of hot winds which have occurred when the earth was wet and the soil full of moisture, and others following some of the wettest seasons that the section over which they occurred had ever experienced. Neither will this theory account for the narrow intensely heated currents often found in the general hot winds; neither will it account for the numerous occurrences of such winds at night, and, further, it will not account for the extreme dryness which is noted in the majority of instances. Furthermore, if these winds were the result of drought and insolation merely, they would not depend on the existence and position of low pressure areas, but would be found prevailing in clear, dry weather whenever severe drought conditions exist. These winds are only found, however, with certain low pressure areas, and, further, during some of the dryest periods on record, their absence is noted.

* The word "insolation" is used to imply local heating at and near the earth's surface by the rays of the sun, including absorption, radiation, and convection.

† Described by Prof. M. W. Harrington in American Meteorological Journal. 8°. Ann Arbor, Mich., vol. 3; 1886, Nov., pp. 330–338; 1887, Feb., pp. 467–475; Mar., pp. 516–523.

‡ Described by Dr. J. Hann in Handbuch der Klimatologie. 8°. Stuttgart, 1883, pp. 208 *et seq.*

In popular opinion the hot winds have been classed with those which carry with them in their progress northward the heat of the climate in which they are supposed to have had their origin; but an examination of the surface conditions prevailing to the south of the hot winds shows that a greater per cent of moisture is always found to the south of them, and that as a rule the general temperatures are lower to the south than over the territory affected by these winds. Therefore general southerly winds do not explain the origin of the special hot winds. Such winds would, moreover, be general, and not confined to the narrow limits often described in connection with these hot winds. Furthermore, this explanation would not be applicable to those hot winds which blow from the north.

The opinion that the general hot winds over the eastern slope of the Rocky Mountains in summer are a special class, and that their heat and dryness are of dynamic origin, the same as that of the foehn and chinook, has been advanced by a few scientists, and the present study of all the observations and correlated facts which can be found relating to this subject certainly appears to confirm the theory that these winds are of such origin. The distribution of pressure in each case where these hot winds have been noted is such as would augment the generally eastward movement of the atmosphere of the middle latitudes. The high pressure off the coast of Oregon and Washington tends to give southeasterly winds between the coast and the divide, and this force acting with the general trend of the atmosphere of these latitudes causes the winds to become more easterly. With these conditions it can readily be seen that an area of low pressure remaining nearly stationary over the eastern slope of the Rocky Mountains for a few days would cause the wind to continue its course across the divide toward such low pressure area. The atmosphere as it moves eastward from the Pacific coast to the crest of the continental divide is always accompanied by clouds and more or less rain, and at the outset is nearly saturated with moisture. In crossing the divide to reach the low pressure area this air must ascend to a height of 10,000 to 15,000 feet. From the deductions of Dr. Hann,* Prof. Bezold,†

* The Laws of the Variation of Temperature in Ascending Currents of Air, etc. Zeitschrift Oest. Met. Gessell., 1874, pp. 321–346, IX.

† Thermodynamics of the Atmosphere, in the Sitzungsb. Ak. Wiss., Berlin, 1888, pp. 485–522.

Prof. Ferrel,* and others, we have learned that saturated air while ascending cools at the rate of about one degree Fahrenheit in each four hundred feet elevation † instead of one degree in about two hundred feet, as is the case with dry air. The reduction of temperature in ascending moist air is compensated about one half by the heat liberated in the condensation of moisture resulting from cooling in the ascent. According to Dr. Hann,‡ one half of the vapor of the atmosphere is below an elevation of 6,000 feet and eight tenths is below 15,000 feet; hence we can readily see how small an amount of moisture can be retained by the atmosphere after crossing a mountain range with an altitude of 10,000 to 15,000 feet. The Central Pacific railroad officials have kept records of the precipitation along the main line of their road from Sacramento to the summit pass for several years. On the result of these records it is stated § that the annual precipitation increases at the rate of one inch for every one hundred feet altitude; that at the summit pass the mean annual precipitation exceeds ninety inches, and that it is not improbable that this amount is considerably exceeded along the crest of the range. Eight tenths of the moisture of our atmosphere is below the crest of those mountains, and air in passing over them loses a large percentage of this moisture. This dry air, in descending over the eastern slope, after having dissipated the cloud carried over, gains temperature dynamically nearly twice as rapidly, in a corresponding distance, as it cooled in ascending the western slope. In moving toward the low pressure area this dry air takes up the circulation around that area, is carried over the plateau region from a northerly direction, and flows down over the eastern slope from a westerly and then a southerly direction, depending on the trend of the isobars. The mass of air, in moving down the slope, loses a great deal of the warmth derived dynamically, by radiation to the earth and the surrounding atmosphere, and also by intermixture, and it

* Recent advances in meteorology; being Appendix 71 to Annual Report of the Chief Signal Officer. 8°. Washington, 1886, part II.

† This is the rate when pressure = 30 inches and temperature = 67°; or p = 25 inches and t = 60°; or p = 20 inches and t = 53°.

‡ Distribution of Aqueous Vapor of Atmosphere with Increase of Altitude. Zeitschrift Oest. Met. Gessell., 1874, pp. 193 to 200, IX.

§ By Capt. C. E. Dutton, in American Journal of Science. 8°. New Haven, 1881; October; no. 130; 3d series, vol. 22, p. 248.

reaches the lower altitudes with dryness and increased temperature, but with less warmth than if the descent had taken place rapidly. The dry air is carried forward in the upper strata more rapidly than in the layers near the earth's surface, and when thus carried out over moister and less dense air its tendency is to descend here and there through that air to the earth's surface, while the moist and less dense air ascends at neighboring points and forms the scattering clouds often noted in connection with these winds. Similar descending currents, on a small scale, have often been observed by the writer to descend on dusty roadways and blow the dust out in all directions, then move off a short distance with the surface wind and die out. These currents (or masses of air) in descending rapidly from great elevations gain a great deal of warmth, and reach the earth with their initial dryness. In order, however, to become so intensely hot they must descend rapidly, or the warmth gained dynamically is lost by radiation. After the earth's surface is reached, both radiation and intermixture become rapid, and each individual current, except in the case of a very large one, is of short duration. This explanation accounts both for the general heating of the atmosphere and for the intensely hot currents, and also accounts for the occurrence of these hot winds at any time of the day or night, from any direction, and without regard to the conditions of the soil, whether wet or dry.

In these descending currents or masses of air evidently very little intermixture with the general atmosphere takes place until the earth's surface is reached. They appear to retain their identity with sharply defined boundaries, to reach the earth with almost extreme dryness, and with warmth gained dynamically when the descent has been rapid. Horizontal layers or currents of dry or moist, hot or cold air interposed upon each other, with the lines dividing them sharply defined, have been noted by observers in balloon ascensions, and the study of these phenomena in this investigation appears to demonstrate that vertical currents may have as sharply defined boundaries, so far as their conditions in relation to the general atmosphere are concerned, as have been observed in connection with horizontal currents.

These hot winds are more frequent between the 34th and 45th parallels of latitude than to the north or south of this territory.

This results from the southern portions of the V-shaped depressions resting generally over this section. The conditions with which hot winds generally occur over this section are shown in plate 4.* The hot winds to the south of the 34th parallel occur with the development of secondary low-pressure areas, as represented by plate 6.* Those to the north of the 46th parallel accompany conditions similar to those which produce the chinook in winter, namely, the low pressure to the north of the Dakotas and Minnesota, with the high pressure over the northern plateau region and extending back toward the Pacific coast, as represented by plate 5.* The conditions which produce the hot winds over the last two sections of the territory named are more rare than the conditions which produce them over that portion between the 34th and 46th parellels of latitude, hence hot winds are not frequent over these sections.

Winds similar in some respects to those general warm winds which occur over the eastern slope may be experienced with a less degree of heat, but intensely dry, over the central valleys and even occasionally eastward on the Atlantic seaboard. Such winds are likely to occur when there is a high pressure area over the gulf and south Atlantic States, another along the Pacific coast, and two or three low-pressure areas slowly follow each other in succession from the eastern slope eastward over the lakes and down the St. Lawrence valley. Low-pressure areas, when moving very slowly and accompanied by brisk to high winds, will, when the high-pressure areas occupy the positions referred to above, draw the atmosphere after them from some distance in the rear, while those moving eastward rapidly would soon leave the atmosphere crossing the divide uninfluenced by their action.

Apparently the conditions on which the development of hot, dry winds over the eastern slope of the Rocky Mountains and eastward depends are the presence of nearly stationary or slow moving low-pressure areas along the eastern slope and then eastward, with a relatively high pressure over the Pacific off the coast of Oregon or in that vicinity. In no instances are hot winds noted with a low-pressure area which moves eastward with any degree of rapidity.

* These plates are omitted here.

Although the development of these hot winds is entirely independent of drought conditions, yet they will, of course, become much more intense, will extend over more territory, and be more injurious to crops when they occur during the prevalence of a drought than when they occur with seasonable weather, as vegetation in the former case will be the principal source from which they must draw their moisture, and the excessively dry winds can injure crops generally in a very short time. When the earth is moist, crops are not likely to suffer seriously during the prevalence of a generally warm, dry wind, but principally suffer where the intensely hot winds occur, resulting from the rapidly descending currents; and the areas affected by these, while they make considerable show, are but a small amount when compared with the entire crop of a State. Occasionally one sixth, or even one fourth, of two or three counties is completely burned up, but such cases are rare. In fact, after a careful consideration of this subject, I have arrived at the conclusion that while these winds are often very intense and striking in their nature, and damage crops to a considerable extent, yet there are other sections of the United States where the farmer has as great drawbacks to contend with, such as overflows, excessive rains, etc.

These winds are a feature of the climate of the eastern slope of the Rocky Mountains, and cannot be expected to disappear or even become less frequent; neither are they likely to become more so, and, while nothing can be done to prevent their occurrence, steps should be taken to ameliorate their effects, if practicable. It appears that anything which would furnish an extended surface from which these hot and dry winds could absorb moisture, and thus by evaporation reduce their temperature as well as increase their moisture, would lessen their geographic extent and their injurious effects on vegetation. A generous growth of hardy timber appears to be the only material suggestion in this connection. If every farmer would hedge his farm and plant tracts of such hardy and long-lived trees as have been found to succeed in similar climates, the injury resulting to crops from these winds might be appreciably decreased. Over much of the territory affected by these winds there is at present a scattering growth of timber, and this should be carefully protected and extended.

THE METEOROLOGICAL SERVICES OF SOUTH AMERICA. — I.

A. LAWRENCE ROTCH.

INTRODUCTION.

THE following account of the meteorological services in the South American states is based upon a personal inspection in 1893. The countries in which meteorological observatories and central stations exist are Peru, Chile, Argentine Republic, Uruguay, and Brazil, but none of them receive telegraphic reports to be employed in the issue of weather predictions or storm warnings.

In Peru, the Harvard College Observatory maintains an astronomical and first order meteorological station near Arequipa, and a system of secondary stations in connection with it. At Lima, a first order meteorological observatory has quite recently been built by the Academy of Medicine. Chile has, at Santiago, the oldest observatory in South America, next to that at Rio de Janeiro, and also the earliest climatological service. The Argentine Meteorological Office, established by Dr. B. A. Gould, of Cambridge, Mass., and now directed by Mr. W. G. Davis, is the headquarters of the only complete climatological service in South America, and will be fully described. The provincial observatory at La Plata is both astronomical and meteorological. In Uruguay, near Montevideo, there is a Jesuit College with a meteorological observatory, and a climatological service has recently been started by a meteorological society. The National Observatory at Rio de Janeiro is an old and well-equipped establishment for astronomical and meteorological work; the general weather service, which was decreed for the Navy Department, has not yet been organized.

PERU.

As already described in this JOURNAL (Vol. ix., p. 282), the Harvard College Observatory has maintained, since 1891, an astronomical and a first-class meteorological station near Arequipa, in latitude 16° 22′ south and longitude 71° 22′ west,

at an elevation of 8,060 feet above sea-level; and, as since stated in the Journal, self-recording instruments have been placed on the summit of the volcano El Misti, 19,200 feet, which thus becomes the highest meteorological station in the world. Other secondary stations extend along the railroad, from Mollendo, on the Pacific Ocean, to Lake Titicaca (12,540 feet).

At Lima (latitude 12° 4′ south, longitude 77° 3′ west, elevation 520 feet) a first-class meteorological observatory, "Unanue," was built in 1892. It is equipped with the Richard self-recording instruments and is supported by the National Academy of Medicine. The director is Dr. M. R. Artola, and the monthly observations appear in the *Boletin de la Sociedad Geografica de Lima.*

CHILE.

THE NATIONAL OBSERVATORY AT SANTIAGO.

The observatory was founded in 1848 by the American Lieutenant Gilliss, on his expedition to observe the transit of Venus, and the instruments were purchased in 1852 by the Chilean government. The first location of the Observatory was on the hill of Santa Lucia, 1,940 feet above the sea and 175 feet above the city, but on account of the disturbance due, partly to the deflections of the rocky summit from the insolation, and partly to the growth of the city around the hill, the observatory was removed in 1860 to the Quinta Normal, a park west of the town. Its latitude here is 33° 27′ south, longitude 70° 41′ west, and elevation 1,700 feet above the sea. In 1852 Dr. C. Moesta, a German, was appointed director, and it was through his efforts that the large equatorial, as well as the meteorological and magnetic instruments were purchased. Dr. Moesta died in Dresden, about 1873, and was succeeded by Sr. J. I. Veraga, a Chilean, who was followed, in 1887, by the present director, M. A. Obrecht, formerly an assistant in the Paris Observatory. A subvention of $2,000 (Chilean) was formerly allowed by the government.

The normal barometer, of the Fortin type, was constructed by Grosch about 1860, and was remounted by the maker in 1881 on a more substantial pier. It agrees closely with the standard of the United States Weather Bureau as already stated in this Journal. A small Fortin is used as a sub-standard.

There is a barograph, constructed in 1873 by Schwandewell, of Dresden, consisting of a balanced tube suspended from a lever and recording each quarter hour on paper which passes under the pencil during five days. This instrument requires a temperature correction. There was formerly a metallic thermograph by the same maker. The thermometers (comprising dry and wet bulbs and a Six maximum and minimum) are exposed on the wall outside the south portal. A Robinson anemometer and a vane are badly exposed on the roof of the main building, about twenty-five feet above the ground, and evidently are sheltered from the northwest winds. They can be read electrically in the house, the direction to 16 points of azimuth.

A rain-gauge, with a collecting surface of a square decimeter, is exposed on the ground. There are two evaporation gauges, one on the ground and the other on the roof. A Ewing seismograph is kept ready for action, and other earthquake instruments have been tried. The record of earth tremors during the last three years shows the extreme movement of the ground to have been one centimeter, while the level observations demonstrate its daily and annual movement.

Prior to 1873 occasional hourly observations were made, and these were continued each tenth day until 1888. From the twenty-four hour mean the corrections to the regular tri-daily observations have been determined. Observations are now made at 7 A. M., 2 and 10 P. M. by one assistant, while two or three others perform the astronomical work, including the time service. An Agricultural School, situated in the same park, possesses some of the self-recording instruments of Richard Brothers, and the observations appeared in the *Anuario* for 1886.

The meteorological observations made at the National Observatory from 1849 to 1868, inclusive, were published, with some gaps, in the *Anales de la Universidad*, and from 1869 to 1874 in the *Anuario de la Oficina Central Meteorolojica*, which contained also observations made at other Chilean stations. The Santiago observations have since been published in three octavo volumes bearing the title: *Observaciones Meteorolojicas hechas en el Observatorio astronomico de Santiago.* These contain the observations 1873–81 (with a summary from 1860), 1882–84, and 1885–87.

THE CENTRAL METEOROLOGICAL OFFICE AT SANTIAGO.

This was established in 1868 with sixteen stations reporting to it, and was managed by a government commission of which L. L. Zegers, professor of physics at the University of Santiago, was, and still is, the secretary. At the present time, along the coast and throughout the central and Andean regions, there are thirty stations, located at lighthouses, schools, etc., all being of the second order, excepting Santiago, where the Observatory and the Agricultural School, already mentioned, possess self-recording instruments. Punta Arenas, in the Straits of Magellan, in latitude 53° 10′ south and longitude 70° 54′ west, is the most southern town in the world, and consequently observations there possess much interest. The early observations by J. P. Schythe, 1853-63, were published in *Anales de la Universidad de Chile,* and later ones, 1871-1872, in *Anuario de la Oficina Meteorolojica.* The lighthouse there was equipped with the ordinary instruments by the Commission in 1886, and results of the observations were published in the *Anuario* for the latter half of that year. Another second order station at the Jesuit Monastery in Punta Arenas was established in 1888. Its observations have been published in the Bulletin of the Observatory near Montevideo and in the Bulletin of the College Carlo Alberto in Moncalieri (Italy). These various observations were discussed by Dr. Hann in 1891 in the *Meteorologische Zeitschrift.*

The teachers observing for the Central Office were formerly paid $300 (Chilean), but now receive $1,000 for this and their school work. The stations are not inspected. The instructions for making the observations are similar to those of Angot for the Bureau Central Météorologique de France. Three daily observations are taken, in recent years at 7.30 A. M., 1.30 and 9 P. M., of barometer, thermometers (wet and dry bulb, maximum and minimum), wind (direction and force), clouds (kind, amount, and direction moving from), and precipitation.

Each tenth day observations are made every three hours and the resulting mean is compared with the corresponding one deduced from the three daily observations. If earthquakes occur, the time, intensity, and direction of the shock, and whether it was preceded or followed by noise, are to be noted.

These observations are centralized monthly at the University of Santiago, and until 1891, up to which time a small annual grant of $200 (Chilean) had been received from the government, the observations were reduced. They have been published by the Commission since 1868 in *Anuario de la Oficina Meteorolojica*, each volume containing the observations for one or two years. In the seventh volume, with the observations 1873–74, there are many typographical errors from the proof-sheets not having been read. With the publication of the 1875 observations, the *Anuario* seems to have lapsed until the publication of those for 1886 was resumed in five parts, and it was thus continued until 1888. The *Anuario Hydrografico de la Marina*, whose issue was commenced in 1875, contains observations made at some of the coast stations.

THE FALKLAND ISLANDS.

The meteorology of these islands is interesting because they are probably the most southerly islands in the world where meteorological observations have been made for a year or more. The islands belong to Great Britain, and the capital, Stanley, situated on the East Falkland, is in latitude 51° 41′ south and longitude 57° 51′ west. Meteorological observations were made by F. E. Cobb, the manager of the Falkland Islands Company, during 1875–77, and a summary and brief discussion of them was given by W. Marriott in 1880, in the *Quarterly Journal of the Royal* (London) *Meteorological Society*. Another series of observations, 1880–86, was made by Capt. Seemann and communicated to the Deutsche Seewarte. The climate of Stanley was discussed by A. von Danckelmann in *Annalen Hydrog. Berlin*, in 1885. The most recent observations were made by Fr. M. L. Migone, a Jesuit priest, from January to May, 1891, inclusive, and printed monthly in the official *Falkland Island Gazette*.

(*To be continued.*)

CURRENT NOTES.

A New Course in Meteorology at the University of California.— The Board of Regents of the University of California has decided to establish a course in meteorology in that University, to be given for the first time during the winter of 1894–95. We quote the following with reference to this new course from an address by Mr. B. S. Pague, Local Forecast Official at San Francisco, before the students of the University of California and the public, at San Francisco, March 14, 1894: —

"The action of the Board of Regents . . . in formally establishing the meteorological course in this university, marks a new era in the advancement and development of meteorological science, especially so in its relation to the material interests of California. Meteorology is old. As an applied science it is in its infancy. It has only been within the past quarter of a century that any real practical work has been done; that any united effort has been made to investigate the atmosphere and to deduce the laws which govern and regulate the origin, development, and movement of storms. The establishment of the Weather Bureau in 1870 attracted public attention to the need of investigating the atmospheric changes; previous to this time knowledge on the subject, so far as the general public, or the public outside of the more technical scientific portion, was concerned, consisted in the proverbs handed down for ages, about the ground hog, what to do and what not to do in the dark of the moon, and others of a similar import; there was generally included in the common school geographies a chapter on physical geography, and gradually papers, articles, and books began to appear more numerously on the subject of meteorology. These are spoken of to show you the gradual development of interest.

"After the work of the Bureau began to demonstrate its usefulness and the value of its forecasts, the more progressive colleges and universities began to take up the study, very crude at first, which with experience has developed, and I can say, without fear of successful contradiction, that the course of meteorology, established by your Board of Regents last night, is the most comprehensive, thorough, and complete of any course in the United States. The course as outlined, if carried on as thoroughly as it is intended to be, will place the student who completes the course among the scientific meteorologists of the country, at once fitting him for a position as instructor in this branch of science, or peculiarly well fitting him for the practical work of the Weather Bureau. The Weather Bureau will co-operate thoroughly with you in the meteorological course and will extend all possible aid to assist the students in an undertaking of the practical work; means will be afforded for the taking of complete observations, for their reduction and application to others, for the receipt at the University of the

Weather Bureau telegraphic reports, so that the students will be enabled to carry on the practical work of a first-class Weather Bureau station, including the making of weather maps and charts and the deduction of forecasts. Under the direction of able professors the student will have the opportunity of becoming proficient in the theory of meteorology and fitted to conduct original investigation. By the practical work he will be prepared to enter the Weather Bureau and take a place, necessarily, at first, as an assistant; but with the groundwork obtained here at the University he will advance more rapidly than those of his less fortunate co-workers, less fortunate, inasmuch that they have not had the advantages of this proposed course.

"The Weather Bureau furnishes employment to some five hundred persons; save in the central office at Washington, where there are a few women, they are all men, in age ranging from twenty to fifty years, ages covering the most useful period of man's existence. The salaries range from $900 to $3,000 per annum, with one professorship at $4,000, and the Chief of the Bureau at $4,500 per annum. The work of the Bureau is such that, though every moment of the time belongs to the government, yet the conditions are such that no matter at what station you may be on duty, there can be found time outside the time required for the performance of official duties to devote to the study of any subject which you may be more interested in, in this manner fitting yourself for any profession or position that your tastes or desires cause you to seek. The foregoing to the prospective student in the new course, for your information and from a practical standpoint what the course may develop for you. I do not wish to be understood that all graduates in this course are offered or promised positions in the Weather Bureau, but rather that all, if so desired, will have the opportunity, with the advantages of a thorough education on the subject, to enter into the examination for positions in the Bureau, and once in the Bureau, advancement and promotion depend not upon by favor, but upon each man's own merit and ability. This view of the practical benefit of the meteorological course is not the most refined or the high and liberal view which should be taken of a scientific study so fruitful of good to fellow-man, but it is presented for its worth.

"Through the course of study and investigation which the students of this new course will prosecute, valuable additions to science are anticipated. Investigation and observation will be made to determine the source of the storms which influence the weather on the Pacific Coast, and to endeavor to deduce such laws as will enable the weather forecasts to be made more accurately for a brief period, and to generalize for a long period of, perhaps months. If successful in this, and there is probability of success, the University of California will enhance her fame, and prove to be more of a benefactor to mankind."

Mean Temperature, Humidity, and Vapor Tension Conditions of the Arabian Sea and Persian Gulf.— In the Indian Meteorological Memoirs, Vol. VI., Part I., Mr. W. L. Dallas, Assistant Meteorological Reporter to the Government of India, has a valuable "Investigation into the Mean Temperature, Humidity, and Vapor Tension Conditions of the Arabian Sea and

Persian Gulf." The following is a short summary of some of the more important points in Mr. Dallas' paper.

The number of observations used in the investigation was 53,700 which, as the period of observation extends over twenty-two years, gives an average of about 2,400 observations a year. The mean temperature for the whole area and for the whole year is 80.1°, and the monthly means range from 76.4° in January to 83.2° in May. May is therefore the warmest month in the year, a fall in temperature occurring with the setting in of the rains, the figures for June and July being 82.0° and 82.4°. In August a further fall takes place (80.2°); September has 80.8°, and in October, when the rains cease and the sky clears, the temperature rises to a mean of 82.0°. The main features of the annual curve are low temperatures between December and February; a rising temperature from the end of February to the end of May; uniform but lower temperatures in June and July, and again in August and September; a sudden increase in October, and a monthly fall of 2.5° between October and December.

The changes of the mean humidity of the whole area, month by month, are comparatively small, the difference between the amount of the lowest and highest means being 10 per cent. The maximum humidity occurs in July, the minimum in January, and there is a fairly steady rise and fall between these months. There is found to be no very sudden increase of humidity at the time of the setting in of the monsoon current, the mean for June being one per cent lower than that for May. The high humidity in May is probably due to the slight air motion at that season, which allows the accumulation of a large amount of moisture in the layer of atmosphere in which the observations were made. On dividing the whole area under discussion into two parts, one from 0°–20° N. Lat., and the other from 20°–30° N. Lat., large differences in the hygrometrical conditions of the two regions are apparent. The true monsoon area, south of 20° N. Lat., has a minimum humidity in April and a maximum in August, while in the sub-monsoon region the minimum is in December and the maximum in May, June, and July.

Regarding the vapor tension, it is found that for the whole area the minimum amount of vapor tension is in January, and it then increases irregularly up to a maximum in May. In June there is a fall; in July, a rise; in August, a fall, and, with the exception of a slight secondary maximum in September, the amount decreases steadily to the January minimum. The column of mean monthly vapor tension shows a steady decrease from east to west and from south to north, except that over the Persian Gulf region the amount of vapor is greater than it is over the northern part of the Arabian Sea. It is found that, instead of having a simple curve of diurnal variation of vapor tension over this area, there are great irregularities in the distribution of vapor during the day, greater even than they are over the land. The observations are very discordant, but the maximum occurs most frequently at 4 P. M., and the minimum most frequently at 4 A. M.

Mr. Dallas' report is illustrated with numerous charts of temperature curves, mean monthly temperatures, vapor tension curves, and mean monthly vapor tension distribution.

*Distribution of Weather Forecasts in New England.** — The distribution of the weather forecasts is probably one of the most important matters that the Weather Bureau has to deal with at the present time. The forecasts as made by the officials at Washington and by the local forecasters scattered over the country are very accurate, and are for a period of time far enough in advance to give very desirable and most useful information. They are given to the public by telegraph and telephone, through the medium of the newspapers, by bulletins on railroad trains, and by mail from the central stations of the Weather Bureau. Hundreds and thousands of people get the daily weather forecasts by these means, and are benefited by them, but there are hundreds and thousands more who do not see the daily papers and who are not near enough to the regular display stations to know what the predictions are. Different systems for giving the forecasts to those in the immediate vicinity have been devised, such as the flag signals, the ball system, the semophore system, flashing electric lights at night, etc., some of which are good and are in operation. Last year, however, the postmaster at Augusta, Me., Mr. Walter D. Stinson, in his efforts to benefit the agricultural interests in his county, began a system of distribution of forecasts which is widely spreading and coming into general favor. Mr. Stinson was receiving the forecasts from Boston daily, at about 11 o'clock A. M., giving the probable weather until 8 P. M. on the following day. He with some simple duplicating process made copies of the messages and mailed them to nearly every post-office in his county. The printed forecasts were invariably received by late afternoon or early evening, and as most of the post-offices in the small villages and towns are in the country stores, they were seen by a great many people during the evening, who came in for a social chat, or for the mail and small trading. This plan was brought to the attention of the Chief of the Bureau by this office, and active steps taken to extend the work into other sections, and with marked success. There are now five distributing centres in New England, from which forecasts are daily sent to five hundred and thirty post-offices. These centres are at Augusta, Me., Concord, N. H., St. Johnsbury, Vt., Northampton, Mass., and Hartford, Ct., the postmasters in each place, except at Concord, N. H., kindly duplicating and mailing the forecasts. Franked cards are furnished from this office addressed to all the post-offices on each list, and a set of logotypes with stamping outfit furnished by the Chief of the Bureau. On receipt of the telegram it is immediately duplicated with the logotypes and the cards stamped and mailed. The system has met with great favor among the patrons of the small post-offices, and they anxiously wait the receipt of the cards. The postmaster at Augusta, who had the plan in operation all last season, reports that farmers were in the habit of driving several miles to town each evening to get the indications and lay their plans for the following day's planting or harvesting.

We see no reason why this system cannot be further extended, and trust that it will not be long before the forecasts can be sent to every post-office in New England.

* From the Bulletin of the New England Weather Service for March, 1894.

Second Annual Report of the Sonnblick Verein. — The Second Annual Report of the Sonnblick Verein (see this JOURNAL, X., September, 1893, 229–231 for notice of the First Report) contains articles on "Observations of Electricity on the Sonnblick," by J. Elster and H. Geitel; "The Telephone Line Rauris-Sonnblick," by A. v. Obermeyer; "The Trigonometrical Measurement of the Height of the Sonnblick"; Summary of Meteorological Observations for 1893, and a List of the Members of the Society. The Report contains a fine view of the Sonnblick and the Hochnarr, taken from the Fraganter-scharte; a view of the observer's room at the summit, and the pictures of Simon Neumayer and Peter Lechner, the observers.

From the observations in connection with atmospheric electricity, it appears that the electrical condition of the summit of the Sonnblick remains practically unchanged during a clear day, as also during the year, and therefore it is seen that the mountain top is above the influences which cause daily and yearly fluctuations of electricity on the earth's surface. During rains, and especially during thunderstorms, the manifestations of St. Elmo's fire are very striking. It was found that in snow storms in which the flakes were large, the St. Elmo's fire was positively, but when the flakes were small, negatively, electrified.

The following are the average values of the principal meteorological elements for the year 1893:—

Pressure: Mean of year, 20,476 in.; mean maximum, 20,945 in.; mean minimum, 19,622 in. Temperature: Mean of year, 19.94° F., maximum of year; 49.64° F.; minimum of year, —25.96° F.; Humidity: Mean absolute, 2.6; mean relative, 86. Cloudiness: Mean, 6.3. Precipitation: In general, 52.36 in.; rain, 4.21 in. Days with precipitation, 252; with rain, 33; thunderstorms, 18; hail, 11; fog, 241; storms, 125. Number of days with north wind, 199; northeast, 158; east, 86; southeast, 30; south, 51; southwest, 166; west, 160; northwest, 173; calms, 72.

*The Rainmakers at Work.** — The rainmakers have been industriously plying their trade in Kansas and Nebraska since the opening of the crop season, and it is reported that they have at least succeeded in convincing a good many people that they possess the ability to draw moisture from the most arid skies under the sun. The Kansas City *Star* of recent date devoted a column to this subject, arriving at the conclusion that "the rainmaker seems to have a peculiar faculty for commencing his experiments just about the time a rain is due, and there have been many remarkable coincidences due to this fact, or else many remarkably successful experiments at rainmaking. The faith of the western people in the processes is based on the seeming success of them."

The Rock Island Railroad Company, the *Star* says, maintains a rainmaking department, for which special cars have been fitted up. The chief assistant rainmaker, in a recent interview, said: "We do not claim to be absolutely able to produce rain. We merely assist nature in the work. At times a certain element is lacking in the atmosphere, and by the use of gases

* From the Monthly Review of the Iowa Weather and Crop Service, May, 1894.

and electricity we believe we are able to furnish what is lacking. What that element is we decline to say."

Down in Kansas, it is said, while the operators were at work, there occurred a destructive rain and hail storm, and now the people whose property was injured are about to bring suits against the Rock Island Company for damages. On the basis of the theory that the company's agents produced the disturbance, the people have a just cause of action. But . . . if the cases come to trial there will be no trouble in procuring a great cloud of witnesses, scientific experts at that, to swear that the so-called rainmakers are in no wise responsible.

Blue Hill Weekly Weather Bulletin.—Since June 1, 1894, Mr. H. H. Clayton, of Blue Hill Observatory, Readville, Mass., has issued a weekly weather bulletin containing a forecast of the weather expected during the week following the day of publication of the bulletin. As stated on the bulletin, the object of the publication is "to give the public the advantage of the latest investigations and discoveries in meteorology, especially in regard to weather periodicity. As a result of investigations carried on at the Blue Hill Observatory, it is found possible to foretell the chief features of the weather for many days or weeks in advance. Experimental forecasts published for two months in the *Norfolk County Gazette* show that rain occurred more than twice as frequently on days when rain was forecasted as on other days, and in six weeks out of eight the warmest day of the week occurred on the day it was forecasted. The warm dry period at the beginning of May was predicted in the published forecasts in the latter part of April, and the cool, rainy period near the middle of May was predicted a week in advance."

As is well known to the readers of this JOURNAL, Mr. Clayton has devoted much time to the study of weather periodicities, and this bulletin is a practical result of his researches. So far, the verifications have been very satisfactory. According to comparisons made by Mr. Paul S. Yendell, of the Boston Scientific Society, the forecasts of weather published in June were eighty-two per cent verified at Boston, and the warm and cool periods came in every instance within twenty-four hours of the predicted times.

The subscription price of the bulletin is one dollar a year. Although Mr. Clayton originally intended to publish the forecasts only during the summer, the support given him has been so encouraging that he has decided to continue it throughout the year.

BIBLIOGRAPHICAL NOTES.

THE RELATION BETWEEN SUNSPOTS AND WEATHER OVER THE BAY OF BENGAL.

W. L. DALLAS. *The Relations between Sunspots and Weather as shown by Meteorological Observations taken on board ships in the Bay of Bengal during the years* 1856 *to* 1879. Indian Meteorological Memoirs. Vol. VI., Part I. fol. Calcutta, 1894. Pages 1-8.

Another contribution to the literature on the relation between sunspots and weather comes to us from India, in the sixth volume of the valuable set of Indian Meteorological Memoirs. The paper is by Mr. W. L. Dallas, Assistant Meteorological Reporter to the Government of India, and deals with the question of sunspots and weather viewed in the light of observations made on board ships in the Bay of Bengal during the years 1856-1879. It is well known that the various investigators of this subject have not been by any means agreed in the conclusions they have reached in regard to the influence of sunspots on weather. While one class has held that high temperatures are the rule at a period of sunspot maxima, the other class has held the contrary opinion, and the same is true in regard to the frequency of thunderstorms and other meteorological phenomena. Of late years the attention of many meteorologists and physicists has been turned more and more to the question of the solar control of meteorological phenomena, such as cyclones, rainfall, temperature, and pressure, of terrestrial magnetism and of the occurrence of auroras. The results have, however, been so contradictory in many cases, that any very definite statement of cause and effect is out of the question at present, whatever it may come to be in the future.

The area of the Bay of Bengal selected by Mr. Dallas as the field of his investigation is between 2° and 6° north latitude, and 86° and 90° east longitude. This district is well removed from any dominating land surface and, as the author says, "may fairly be presumed to exhibit uninfluenced solar action on the free atmosphere of an oceanic tract." Over this area, both the annual periodic and the aperiodic changes are very slight, and there is little effect of changes occurring in distant regions, as the horizontal movement of the air is slight. Further, being a sea surface area, there is little liability to the sudden changes which affect a land observatory and result from irregularities of the topography around an observatory.

From a study of the curve of mean annual pressures and the sunspot curve, it is found that there is a striking similarity between the two curves. The number of years during which the number of sunspots exceeded the normal average coincides with the number of years during which the pres-

sure was below the average, and *vice versa.* The maximum pressure differences, whether above or below the average, occur one year after the maximum sunspot variations in both directions.

With regard to temperature Mr. Dallas finds that there is a general defect of temperature when the number of sunspots is low, and a general excess when the number of sunspots is high, but no exact relation between the two phenomena is shown. Mr. Dallas' conclusion is that the figures and curves appear to afford confirmatory evidence that, side by side with other variations, there exists in certain classes of terrestrial phenomena an eleven-year cycle agreeing to a certain extent with the eleven-year cycle in the solar spots. As opposed to this, there is the fact that, so far as these observations show, there is no connection between the actual number of spots and terrestrial weather.

It may be noted that Blanford, in the report on the Meteorology of India in 1884, states that "on the evidence of land stations in the Indo-Malayan region . . . the epoch of sunspot maximum approximately coincides with that of minimum pressure in the Indo-Malayan region."

Mr. John Eliot, in a note to Mr. Dallas' report, calls attention to the fact that the observations made at Bombay, Colombo, Naucowry, Port Blair, and Batavia show that the means deduced from the ships' observations used by Mr. Dallas are not always reliable, and cannot be accepted as representing the actual variations of the years in the sea area in question, unless confirmed by other evidence, as, for example, that of neighboring land stations. This fact, Mr. Eliot says, must be taken into consideration, although it does not necessarily invalidate the general conclusions of Mr. Dallas.